



## Approaches for the Mitigation of Water Quality Functions of Impacted Wetlands – A Review

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**PURPOSE:** This technical note describes current approaches to wetland mitigation for the loss of water quality functions of impacted wetlands. The overall objectives of this document are to (a) describe Corps of Engineer procedures for evaluation and mitigation for the loss of water quality functions, and (b) review state-of-the-art knowledge of wetland functions with regard to water quality. Information from Corps guidance documents and experiences and literature sources such as peer-reviewed scientific journals and other state and Federal guidance documents has been compiled, and input from Corps regulators was solicited in the development of this document.

**BACKGROUND:** Wetland mitigation is the restoration, creation, enhancement, and, in exceptional circumstances, preservation of wetlands and other aquatic resources expressly for the purpose of providing compensatory mitigation in advance of authorized impacts to similar resources (Federal Register 1995). Thirteen functions and values that may be considered by the Corps Regulatory Branch in Section 404 wetland permit applications are listed in Table 1. Quite often many of these functions and values are evaluated, with emphasis on one or more usually providing guidance for mitigation or restoration. Successful mitigation for loss of functions must account for the complexity of the interactions of these functions and values while balancing environmental and economic needs of a region. This approach, referred to as wetland functional analysis (the determination of the functions performed by a wetland and the degree to which each one is performed (Zalidis and Gerakis 1999)), provides a means to identify important functions for management decisions. This approach can also be used at the regional, watershed, or landscape level, which is critical to concepts relevant to plants and wildlife such as patchiness and fragmentation. Major topics in recently published literature that provide a good background for review include assessment techniques, loss and substitution, success and lag times, cumulative impacts, mitigation ratios, and mitigation banking.

**Table 1**  
**Functions and Values of Wetlands**

Functions	Values
Groundwater Recharge/Discharge	Recreation
Sediment Stabilization/Shoreline Erosion	Education/Scientific Value
Floodflow Alteration	Uniqueness/Heritage
Fish and Shellfish Habitat	Visual Quality/Aesthetics
Sediment/Toxicant Retention	Threatened or Endangered Species Habitat
Nutrient Removal/Retention/Transformation	
Production Export	
Wildlife Habitat	

**EXISTING GUIDANCE AND CORPS OF ENGINEERS EXPERIENCES:** General Corps guidance for mitigation is found in several legislative documents such as Section 404 of the Clean Water Act, National Environmental Policy Act (NEPA) (1970), and the Water Resources Development Act. Additional guidance, which tends to be more specific, can be found in (a) the Memorandum of Agreement (MOA) Between the Environmental Protection Agency and the Department of the Army Concerning the Determination of Mitigation Under the Clean Water Act Section 404(b)(1) Guidelines, dated February 6, 1990 (U.S. Environmental Protection Agency 1990), (b) Federal Guidance on the Use of In-Lieu-Fee Arrangements for Compensatory Mitigation under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act (signed in October of 2000, referenced as Federal Register 2000), (c) Federal Guidance for the Establishment, Use, and Operation of Mitigation Banks, (Federal Register 1995), and (d) Corps permit regulations in Title 33 Code of Federal Regulations (CFR) Parts 320 through 330. Regulatory Guidance Letters (RGL) issued by the Corps, RGL 0101, RGL 93-02, and RGL 95-01, the January 1992 MOA with the Environmental Protection Agency (EPA) and the Departments of Agriculture and Interior, and the Nationwide Permit 29 (June 1995) also provide specific related guidance. An overview of the Corps regulatory program is also provided at <http://www.usace.army.mil/lrc/reg/oceover.htm>.

In general, these documents are designed to meet a national goal of "no overall net loss of wetlands." Policy provided in the 1990 MOA includes the Council on Environmental Quality definition of mitigation in its regulations at 40 CFR 1508.20 that includes: avoiding impacts, minimizing impacts, rectifying impacts, reducing impacts over time, and compensating for impacts. The sequence to accomplish this goal is (a) Avoidance (no discharge shall be permitted if there is a practicable alternative), (b) Minimization (adverse impacts should be minimized with project modifications and permit conditions), and (c) Compensatory Mitigation (required for unavoidable adverse impacts remaining after minimization). Compensatory mitigation should include on-site mitigation before off-site mitigation, consideration to loss of functional values, in-kind mitigation before out-of-kind mitigation, consideration to likelihood of success, and restoration as a first option. Mitigation sequencing is established by the 1990 CE/EPA MOA. In-lieu-fee arrangements and mitigation banks may also be used to meet the goal of no net loss (Federal Register 1995, 2000). Guidelines for mitigation have been established by NEPA and, as stated in Brown and Lant (1999), are listed below:

- a. Avoiding the impact altogether by not taking a certain action or parts of an action.
- b. Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
- c. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
- d. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
- e. Compensating for the impact by replacing or providing substitute resources or environments. If compensation must be used, the preferred order of methods is: 1) restoration, 2) creation, 3) enhancement, and 4) preservation, the latter two with reference to existing wetlands under threat of conversion.

The recently issued Guidance Letter (RGL-01-1) lists the types of compensatory mitigation as (a) Establishment, (b) Restoration (including reestablishment and rehabilitation), (c) Enhancement, and (d) Protection/Maintenance. This guidance also adopts definitions that were developed for accounting (i.e., credits and debits), promotes a regional and ecosystem approach by Districts for formulation of compensatory mitigation projects, and addresses responsibility for success and management issues such as monitoring periods.

There is no national policy for the use of fixed ratios for mitigation. Draft guidelines for mitigation banking issued by EPA Region IV in 1992, as reported in Dennison and Schmid (1996), include ratios of 2:1 for restoration, 3:1 for creation, 4:1 for enhancement, and 10:1 for preservation. These draft guidelines may provide a starting point for establishing ratios but considerable attention for flexibility, small landowners, and regional considerations should be included in decision-making. A flexible and regional approach rather than a rigid application of the above ratios is preferred by most Corps Districts and accepted by other regulatory agencies. The level of mitigation must be "appropriate" (based solely on the values and functions of the impacted resource) and "practicable" (defined in Section 230.3(q) as available and capable of being done after taking into consideration cost, existing technology and logistics in light of over all project purposes (Section II.B of the 1990 MOA)).

Application of guidance from these documents has been tailored by several Corps Districts and in collaboration with various state agencies. The **St. Paul District** currently uses guidelines developed from 30 compensatory sites in Minnesota and Wisconsin that establish (a) goals for replacement and self-maintaining systems that mimic the natural hydrology and the permit includes specific requirements for measuring success, (b) criteria for design and construction, and (c) guidance for monitoring, management, and long-term protection (Eggers 1992). "The Minnesota Wetland Evaluation Methodology for the North Central United States" (U.S. Army Engineer District, St. Paul 1988), jointly prepared by the Corps of Engineers and the Minnesota Environmental Quality Board Wetland Evaluation Methodology Task Force, includes a statement of purpose to provide a standard procedure to assist the professional in rapidly evaluating the many functions, values, and characteristics of wetlands. The standard procedure is applied to remove arbitrariness, add reproducibility, enhance (not replace) professional expertise, and allow a multi-function focus for decision-making. The method includes a computer model that builds from flood flow characteristics and includes water quality functions (sediment and nutrient retention), wildlife, fish, shoreline anchoring, and visual values to calculate an overall value. Weighting factors can be applied and the application follows the use of professional judgment, understanding of a reason for a rating (e.g., the rater is familiar with the system), employs comments such as "don't know" and "peculiar results" as a basis for additional studies, and incorporates the idea that all wetlands have value (maintains the no-net-loss concept). The method can be used for before and after comparison. Flood flow characteristics can be broken down for large and small watershed methods and incorporate watershed delineation, precipitation, runoff curve numbers, time of concentration, water body routing, and outlet information. Water quality characteristics are linked to flood flow characteristics with sediment and nutrient retention estimates based on Stoke's Law (settling from flood flow) for grain sizes and relations of phosphorus to grain size (qualitatively derived from land use). Wetland trapping efficiency can also be estimated.

The Regulatory Branch of the **Charleston District** has established a Standard Operating Procedure (SOP) for Compensatory Mitigation, RB-SOP-96-01. The procedure is applicable to regulatory actions requiring compensatory mitigation for adverse ecological effects where more rigorous, detailed studies (e.g., HGM, WET, HEP) are not practical or necessary. The procedure does not address mitigation for categories of effects other than ecological (e.g., historic, cultural, aesthetic). The **Savannah District** has developed an SOP (available at [www.sas.usace.army.mil/permit/secl1.rtf](http://www.sas.usace.army.mil/permit/secl1.rtf) with appendices and worksheets at [www.sas.usace.army.mil/permit.htm](http://www.sas.usace.army.mil/permit.htm)) that is similar to the Charleston District SOP and includes methods for mitigating impacts to streams. Rigid ratios are used for general information and, applied with a “rule of thumb” approach, provide a starting point that is accepted by other regulatory agencies for small actions. The SOP is not typically applied for larger scale impacts such as those associated with large civil works projects. The **Los Angeles District** also uses a flexible approach to mitigation rather than rigid ratios based on type (e.g. restoration, preservation, etc.). Physical and biological functions at the impact site are evaluated and the amount of functional loss is determined with ratios set accordingly. The hydrogeomorphic (HGM) method (Smith et al. 1995) is used for larger projects and a guidebook has been developed for the area. A modified or streamlined version of the HGM is used for smaller projects if data are available. Qualitative evaluations are used when data are lacking. The **Buffalo District** conducts individual evaluations with site-specific data and mitigates accordingly. Many of their projects are not easily classified into traditional schemes that allow easy and acceptable applications of established mitigation procedures. The **Alaska District** has developed a wetland assessment methodology to evaluate functions and values. Decisions are still made on a case-by-case basis for Anchorage, but not for the outlying areas.

The Regulatory Division of the **New England District** has developed a checklist for the review of mitigation plans that is revised periodically as necessary. Detailed guidance for a descriptive approach to wetland functions and values in the New England District can be found in “The Highway Methodology Workbook Supplement,” developed with the Connecticut and New Hampshire Departments of Transportation. The workbook and other information can be found by clicking on Regulatory Programs at [www.nae.usace.army.mil](http://www.nae.usace.army.mil). The Regulatory Division of the New England District “advocates a qualitative, descriptive approach to wetland assessment based on consensus of an interdisciplinary team of professionals.” The New England District does not accept the Wetland Evaluation Technique (WET II), since it is “not regionally sensitive and does not consider wildlife habitat corresponding to the concerns of the Corps, particularly as expressed by the U.S. Fish and Wildlife Service.” The New England District also recommends avoiding numerical methods if supporting data are not readily available and arbitrary weighting should not be applied, and dissimilar functions should not be ranked.

The **Baltimore District** (in conjunction with the Natural Resources Conservation Service) developed sampling methods and a data collection protocol for the HGM (Vasilas, Minkin, and Yanchik 1999). Sampling includes constituents for assessing water quality functions such as soil properties, water chemistry (e.g., nitrogen, phosphorus, heavy metals), Eh (oxidation/reduction potential), and soil organic carbon. The data collection protocol includes characterization of the site and a reference site and methods for sampling including recommendations for quarterly or seasonally sampling for water quality.

**Wilmington District** uses a compensatory mitigation planning checklist that includes questions about target goals and functions, success criteria, use of a reference ecosystem, water sources and water budget, monitoring, and potential for failure. **Portland District** experiences were summarized by Lightcap (unpublished) and general conclusions emphasized the need to follow up with compliance and to conduct report evaluations in a timely manner. A mitigation questionnaire was also developed for use.

## GENERAL WETLAND CONCEPTS

**Assessment Techniques.** Bartoldus (1999) provides an excellent review of 40 wetland assessment procedures. Of the 40 methods reviewed, 27 methods included water quality assessment procedures to some extent. In general, most of these methods use a ranking method often combined with weighting and are typically intended for rapid application. This approach often uses easily obtained information that suggests potential or opportunity for water quality functions (e.g., source of pollutant in the upstream watershed, detention time, ponds, etc.). Only a few methods offer a more quantitative approach but typically require more effort (e.g., time, money, expertise) to apply. Some of the more recently developed methods have also been evaluated and categorized as logic or mechanistic by Hruby (1999). Hruby points out that the current rapid assessment methods do not assess rates or dynamics of ecological processes occurring in wetlands but they do allow a way of organizing current knowledge, including subjective observations. Three general criteria were common to the methods reviewed:

- a. An image of characteristics found for the highest performing wetland was compared to the ideal.
- b. Reference standards for each function in a region were used for comparison.
- c. The least-altered reference in a region (reflecting the highest performance for all functions) becomes the standard.

Some of these methods (e.g., the Indicator Value Assessment (IVA) (Hruby, Cesanek, and Miller 1995)) are not actually methods but are intended to provide guidance for developing regionally specific methods (Hruby 1999).

**Loss and Substitution.** Prior to the 1990 MOA and the no-net-loss concept, Kentula et al. (1992) reported a net loss of 32 ha (43 percent of impacted wetlands) in Oregon between January 1977 and 1987 and 16 ha (26 percent of impacted wetlands) between 1980 and 1986 in Washington. Recent studies have indicated that there is often a net loss in wetland function that may be attributed to substitution of one wetland type or function for another such as creation of an upland freshwater system as mitigation for loss of a tidal, brackish water wetland. In evaluating 75 projects in southern California (Los Angeles District), Allen and Feddema (1996) reported that an average mitigation ratio of 1.4:1.0 (mitigated to impacted) still resulted in a net loss of 3.14 ha of wetland resources in the years 1987-1989. General conclusions suggested that freshwater wetlands were experiencing a disproportionate loss of area, riparian woodland wetlands were most often used in mitigation efforts, and large-scale projects were typically more successful. Recommendations included better monitoring, in-kind mitigation, and banking at a regional/watershed level.

**Success and Lag Times.** The success of compensatory-mitigation wetlands is difficult to measure within regulatory time frames for most attributes and a lack of long-term data sets limits the ability of indicators that reveal potential for success to be used for long-term predictions. Natural variability in created and reference sites may also limit short-term comparisons. Success of a created wetland is often defined based on the establishment of vegetative cover (e.g., 75 percent cover of indigenous wetland vegetation within two growing seasons is included in regulations used in Massachusetts as reported in Jarman et al. (1991)). This approach assumes that functions will be similar if the size of the created wetland is the same as the impacted area and the created wetland is located at the same elevation as the impacted area. Success is most often achieved when these conditions are met and soils from the impacted site are used in the created wetland, hydrology is similar, and there is a connection to existing wetlands. Simenstad and Thom (1996) found that only a few of 16 ecosystem attributes analyzed for a restored wetland showed functional trajectories comparable to natural wetlands. A review of mitigation projects in the San Francisco area, Texas, Florida, New Jersey, and Virginia indicated that many projects are failing and there is a need to improve compliance (Race and Fonesca 1996), suggesting that lack of success is not a regional problem.

Wilson and Mitsch (1996) found four of five replacement wetlands to be in compliance with legal requirements, indicating that there can be success. The four wetlands were considered to demonstrate medium to high ecosystem success using hydrology, soils, vegetation, wildlife, and water quality functions as indicators of success. A replacement ratio of 1.4:1 was found for the four wetlands and substitution was generally avoided by replacement of depressional wetlands with depressional wetlands. Erwin et al. (1994) demonstrated that the use of material from the site to be impacted and construction of compensatory wetlands in the same area can be successful and fully functional marshes can be established in a little over 2 years.

A recent study by Mitsch and Wilson (1996) suggested that 15-20 years may be required (rather than 5 years) to judge the extent of success for freshwater marshes and longer periods of time may be required for wetlands that are forested, coastal, or peatlands. Kusler and Kentula (1990) suggested that the success of creating forested wetlands is often lower than herbaceous freshwater wetlands and is likely related to appropriate hydrologic regimes. In a comparison between a constructed wetland and a reference system after 5 years, Zedler and Langis (1991) noted that 10 of 11 factors or indexes still lagged. Factors evaluated included organic matter content, sediment nitrogen (inorganic), sediment nitrogen (total Kjeldahl nitrogen), pore-water nitrogen (inorganic), nitrogen fixation in the upper 1 cm, nitrogen fixation in the rhizosphere, biomass of vascular plants, foliar nitrogen concentration, height of vascular plants, epibenthic invertebrate numbers, and epibenthic invertebrate species. Only nitrogen fixation in the rhizosphere was greater in the created wetland than in the reference wetland. Zedler and Callaway (1999) concluded that even after 10 years, a constructed marsh in San Diego Bay was not meeting compliance expectations and that periods of time greater than 10 to 40 years may be required for expected soil conditions to develop to those of natural wetlands.

The time it takes for compensatory mitigation wetlands to attain a desired level of function will vary by the functions to be obtained. Hydrology is probably the most important factor for determining the establishment and maintenance of specific wetland functions (Mitsch and Gosselink 1993). Sifneos, Kentula, and Price (1992) point out the difficulty in tracking wetland progress for

mitigation sites and recommend incorporating lag times between creation and attainment of function into the Section 404 decision process.

**Regional and Landscape Considerations.** Consideration of wetland functions and values in regional, watershed, or landscape scales is also recommended (Zedler 1996a) since mitigation can alter the distribution of wetland types and functions over large geographic areas (Bedford 1996), although additional ecological studies to identify limits to ecosystem development are needed to set performance standards (Zedler 1996a). A landscape approach will certainly be useful in assessing cumulative impacts. Bedford (1996) has suggested that defining hydrologic equivalency, with climate and hydrogeologic setting as key variables, is conducive to the landscape approach. This approach accounts for (a) the relative importance of water sources (compatible with suggestions by Brinson (1993), (b) mineral element and nutrient content (geology and source water), and (c) spatial and temporal dynamics of water (hydrodynamics such as velocity, hydroperiod, and residence time) (Lugo et al. 1990, Brinson and Lee 1989, Brinson 1993), water movement within and between adjacent systems, and material exchange that results (see Gosselink and Turner (1978)). The source of water (e.g., precipitation, overland flow, groundwater) can result in a gradient in wetland functions (Brinson 1993), which can require regional considerations.

Bedford (1996) suggests that implementing a landscape approach would require several efforts such as determining appropriate accounting units (e.g., ecoregions developed by Omernik (1987) or hydrologic boundaries), utilization or development of Geographical Information Systems (GIS) databases, and cooperative efforts between Corps Districts, state agencies, and other stakeholders, as well as a framework to administer the cooperative efforts. Reestablishment of habitats that have been most reduced in area or species may be a reasonable way to develop regional priorities (Zedler 1996b). GIS methodologies can be combined with predictors or indicators from wetland assessment techniques to develop landscape-level assessments (Cedfeldt, Watzin, and Richardson 2000).

**Cumulative Impacts.** A cumulative impact is defined as: "... the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 CFR Sect. 1508.7) Assessment of cumulative impacts using a synoptic approach has been proposed by Leibowitz et al. (1992) that incorporates the regional or landscape level concept of wetland functions and values. Five major steps are used in conducting a synoptic assessment: (a) define goals and criteria, (b) define synoptic indices, (c) select landscape indicators, (d) conduct the assessment, and (e) prepare synoptic reports. MacDonald (2000) provides a similar approach that includes a scoping phase, an analysis phase, and a planning and management phase, with each phase consisting of two to five discrete but interrelated tasks. Tasks include issue and resource identification, definition of time and spatial scales, risk assessment, evaluation of cause-and-effect mechanisms, estimations of natural variability and resource conditions, consideration of past, present, and future conditions and impacts, and development of effective monitoring plans that allow for modification.

In a review of cumulative impact assessments of five Environmental Impact Statements (EISs), Canter and Kamath (1995) reported that each of the EISs incorporated a checklist in the cumulative impact assessment but the extent of each checklist varied. The most extensive assessment included

quantitative data from mathematical modeling associated with a court decision that determined the original cumulative impact assessment was deficient. Based on this review, a generic checklist to assess cumulative environmental impacts, originally developed by Kamath (1993), was proposed. It was recognized that the checklist may not be applicable to all projects but it should provide a general framework for assessing cumulative impacts.

A regional or landscape approach to assessing wetland functions is directly related to assessing cumulative impacts. Identification of the kinds, numbers, relative abundances, and spatial distribution of wetlands in a region, both past and present, can be used in decision-making for restoration (Bedford 1999) and mitigation.

**MITIGATION RATIOS:** Mitigation ratios are determined by the Corps of Engineers to equal or exceed the performance of the damaged site and are usually expressed in acres of compensatory mitigation wetland to acres of impacted wetland. Mitigation ratios are often determined with little information on the site to be impacted and even less information on the potential for the mitigation site to meet mitigation criteria. Decisions on mitigation ratios are often based on application of an assessment technique as described above and in conjunction with best professional judgment of an interdisciplinary team. In some cases, a regional or landscape approach may be applied. Input from other agencies and interested parties is often included in the process. Guidance provided in the 1990 MOA suggests that "in the absence of more definitive information on the functions and values of specific wetland sites, a minimum of 1 to 1 acreage replacement may be used as a reasonable surrogate for no net loss of functions and values." Ratios are based on area and are typically between 1:1 and 4:1 but can be less than 1:1 in specific cases (Zedler 1996a, 1996b) or greater than 4:1 (e.g., recommended for preservation). Ratios that are less than 1:1 are typically proposed for degraded wetlands where compensatory mitigation sites are designed to be smaller, but of a higher quality for selected functions. The 1990 MOA indicates that higher ratios may be needed where the functional values of the impacted area are "demonstrably high" and will be replaced by wetlands with lower functional values. Conversely, a lower ratio may be acceptable if the functional values of the impacted area are "demonstrably low" and there is a high likelihood of success with the proposed mitigation. Establishing ratios is also difficult since the area of a wetland and the functions of a wetland do not have a one-to-one correspondence (Brinson 1995). As pointed out by Wilson and Mitsch (1996) and Zedler and Langis (1991), all of the functions lost in a fill site may not be replaced even when mitigation ratios exceed 1:1.

Determining mitigation ratios can be difficult, since consideration must be given to differences between functions and values at existing versus mitigated sites, which are not usually the same. The net result is that a function or value that is considered to be the most important or critical is used to determine an acceptable mitigation ratio. This may occur at the expense of other functions and values, is not always agreed to by interested parties, and may actually not meet no-net-loss objectives if there is a function or value that is inadequately addressed. There is some support for this ranking, prioritization, or trade-off approach, since not all wetlands have the same functions and values.

Several methods of determining compensation have been recently proposed. King, Bohlen, and Adler (1993) developed a framework for determining mitigation ratios that is comparable to the HEP method, including a mechanism for dealing with lag, and adds mechanisms to incorporate expected

success and a discount rate (based on economic methods). MacDonald, Bergstrom, and Houston (1998) proposed a binary response estimation procedure that uses contingent valuation data for estimating incremental benefits associated with constructed wetlands used to control agricultural non-point source pollution. The methodology was able to measure non-water quality benefits (e.g., values and functions) of constructed wetlands that were implemented for water quality improvement and the authors suggest that the added values and functions need to be accounted for in economic analyses and management decisions. At a watershed level, Fustec et al. (1999) have developed a methodology for multifunctional assessment of riverine wetlands that focuses on water supply, flood control, nutrient retention, and connectivity to channels for fish communities. General conclusions from the study indicated a need to utilize wetland classification on a hydrogeomorphic basis, then develop a multifunctional assessment in reference zones with indicators or models (Fustec et al. 1999).

Guidance in setting mitigation ratios includes consideration of the perceived value of the impact site, the difficulty in replacing values, and the time lapse (lag) anticipated between impact and compensation (Zedler 1996a). Hypothetical models, pathways, and trajectories (Aronson and Le Floc'h 1996; Hobbs and Norton 1996; Simenstad and Thom 1996; Dobson, Bradshaw, and Baker 1997; Meffe et al. 1997), as described in Zedler and Callaway (1999) offer an approach to allow development of mitigation ratios based on expected replacement with compensatory mitigation. However, Zedler and Callaway (1999) point out that there has been relatively little documentation of the effectiveness of this approach and offer alternative management and mitigation policies including recognition that (a) compensation sites may never fully replace natural wetland functions, (b) the time to functional equivalency may well exceed the usual monitoring periods, and (c) long-term predictions of the time to functional equivalency may not be meaningful if they are based on short-term data from pulse-driven systems. Using this concept, Zedler and Callaway (1999) suggest that where functional replacement is unlikely, either the permit for the proposed damages should be denied or mitigation ratios should be adjusted to a maximum value that is relative to the site. However, the applicability of trajectories in predicting restoration success varies by factors such as the severity of the damage, ecosystem type, and restoration techniques.

Brinson and Lee (1989) suggest that a goal for mitigating losses should be to replace ecosystem processes, not just duplicate vegetation. This approach included replacement of hydrologic, geomorphic, and nutrient conditions and provided a foundation for developing many of the assessment approaches used today. Roberts (1993) discusses wetlands trading and provides commentary from several notable wetland scientists that reflects opinions from at least some of the academic and institutional wetland experts. For example, the National Research Council concluded "Wetland restoration should not be used to mitigate avoidable destruction of other wetlands until it can be scientifically demonstrated that the replacement ecosystems are of equal or better functioning." Roberts (1993) reports that many wetland scientists advocate strict, agreed-upon standards to judge success, long-term monitoring, and a commitment from the developer to make mid-course corrections when needed. Roberts also summarizes the philosophy of many wetland scientists that suggests "the decision of whether to permit the destruction of a wetland ... be based on whether we can afford to lose that system, not whether we can replace it."

**MITIGATION BANKING:** Wetland mitigation banks are normally relatively large blocks of wetlands whose estimated tangible and intangible values, termed credits, are similar to cash deposits

in a regular checking account (Reppert 1992). The concept of mitigation banking was developed to replace wetland function and values unavoidably lost through development. Mitigation banking should also consider concepts of no-net-loss of area, function, and value, impacts of substitution, assessment techniques, measurements of success (accounting for a potential lag), regional and cumulative impacts, and socioeconomic benefits. Information and guidance regarding mitigation banking can be found in reports prepared by the Institute for Water Resources (IWR), U.S. Army Corps of Engineers (Brumbaugh and Reppert 1994, Environmental Law Institute and Institute for Water Resources 1994). Stein, Tabatabai, and Ambrose (2000) provide a detailed framework for crediting and debiting in wetland mitigation banking that incorporates many of the above concepts. However, Brown and Lant (1999) reported that only 74 percent of the 68 banks evaluated throughout the United States through January of 1996 are achieving no net loss by acreage. Overall, wetland mitigation banks were projected to result in a net loss of over 21,000 acres nationally and 52 percent of the acreage in banks is converted to other uses (substitution of wetland type). Furthermore, banking may facilitate geographic relocation of wetlands that could considerably affect cumulative impacts.

**MITIGATION FOR LOSS OF WATER QUALITY FUNCTIONS:** In general, sediment and toxicant retention, nutrient removal, retention, or transformation, and production export (the effectiveness of the wetland to produce food or usable products for humans or other living organisms, e.g., fisheries, organic carbon export) comprise the water quality functions for purposes of this report. Considerations and qualifiers for these three functions are summarized below with information from methodology provided by the U.S. Army Corps of Engineers (1995). General requirements for sediment and toxic retention include a potential source in the watershed, opportunity for trapping in the wetland, fine-grained or organic material present in the wetland, and opportunity for aerobic and anaerobic processes. Site hydrology and type and extent of vegetative cover also play a critical role in the ability of a wetland to retain sediments and toxicants. Requirements for nutrient removal, retention, and transformation are similar to those of sediment and toxicant removal and may also be positively related to a large wetland relative to the size of its watershed. Vegetation density and ability to utilize nutrients and site hydrology are both critical to nutrient removal, retention, and transformation. Requirements for production export include growth of wildlife food sources within the wetland, development of detritus, economically or commercially used products present in the wetland, use by wildlife and higher trophic level consumers, presence of fish or shellfish, dense vegetation, diverse plant community structure, and export of nutrients and organic material. However, it must be pointed out that it is very difficult to separate out individual functions and values since they are interrelated. Even when individual water quality functions are measured, estimated, or qualitatively ranked, comparison to functions provided by a mitigation site may be difficult, since they are likely to vary.

Clearly, characteristics ascribed to water quality functions must be present or planned for in compensatory mitigation. Hydrology must be sufficient to provide comparable conditions of material transport and retention, inundation frequency and duration, and supply to vegetation in the mitigation site to conditions lost by the impacted site. As pointed out by Brinson et al. (1997), wetland functions are not independent aggregates but are correlated, integrated, and complex processes that are not easily separated. Water quality functions can be defined this way as well.

While replacement or even improvement of water quality functions associated with filling of a wetland can often be accomplished with sound engineering designs such as those used in constructed wetlands, these structures may not adequately provide for other desired wetland functions such as wildlife habitat or values such as aesthetics. Mitigation designs that focus on sustainable replacement of lost in-kind functions and values (i.e. wildlife habitat for threatened and endangered species) may require a much longer period of time to develop. Even projecting the potential for meeting mitigation criteria at the mitigation site may not be rigorous enough to determine compensatory requirements.

Recognizing that not all wetlands are capable of providing all functions and values, or that there is often a local/regional desire of wetlands to provide selected functions and values, mitigation for the loss of water quality functions must be tethered with local/regional needs and evaluated with other obtainable functions and values. While this promotes the concept of wetlands as aggregates of functions (Brinson et al. 1997), it may be useful in certain applications. For example, applicants trying for less than a 1:1 mitigation ratio by increasing functions of degraded sites need to recognize that this approach could result in a net loss by acres, promotes patchiness and fragmentation, and can result in increased substitution. Conversely, over-compensation (on an areal basis) is also possible if mitigation attempts to compensate for individual loss of functions. Approaches that use an overall functional assessment or identify a mitigation ratio based on the most desired functions seem to offer an acceptable compromise. Mitigating for loss of water quality functions of wetlands can be expanded within these approaches.

**INTERAGENCY COLLABORATION:** Some consideration should be given to views, guidelines, and recommendations from interagency and interdisciplinary collaborations. For example, the National Research Council (NRC) has released a document for public comment entitled "Compensating for Wetland Losses Under the Clean Water Act." The document was prepared by a committee established by the NRC (Committee on Mitigating Wetland Losses). Principal findings and recommendations presented in the executive summary are summarized below:

- **Conclusion:** The goal of no net loss of wetlands is not being met for wetland functions by the mitigation program, despite progress in the last 20 years.

**Recommendations:** The wetland area and functions lost and regained over time should be tracked in a national database. This database could include the Corps of Engineers' Regional Analysis and Management System (RAMS) database, which the Corps should expand and improve data entry procedures. The Corps, in cooperation with states, should encourage the establishment of watershed organizations responsible for tracking, monitoring, and managing wetlands in public ownership or under easement.

- **Conclusion:** A watershed approach may improve permit decision making.

**Recommendations:** Sites should be selected on a watershed scale in order to maintain wetland diversity, connectivity, and appropriate proportions of upland and wetland systems for self-sustainability, long-term stability, and regional biological dynamics. Additional specific recommendations were provided.

- **Conclusion:** Performance expectations in Section 404 permits have often been unclear, and compliance has often not been assured or attained.

**Recommendations:** General goals focused on design and construction of mitigation sites to maximize the likelihood that they will be an ongoing ecological contribution to the watershed. The sites should be in place concurrent with, and preferably before, the permitted activity, and there should be effective legal and financial assurances for long-term sustainability and monitoring. Additional specific recommendations were provided.

- **Conclusion:** Support for regulatory decision-making is inadequate.  
**Recommendations:** A reference manual should be developed (by the Corps for regions) and the Corps and other regulatory authorities should fund staff participation in training opportunities. The Corps and other regulatory authorities should establish a research program to study mitigation sites and determine effective practices for long-term performance. States, with federal agencies, are encouraged to prepare technical plans for wetlands on a regional basis.
- **Conclusion:** Third-party compensation approaches (mitigation banks, in-lieu fee programs) offer some advantages over permittee-responsible mitigation.  
**Recommendations:** Institutional systems should be modified to provide third-party compensatory mitigation for timely and assured compensation. The Corps and EPA should work with the states to expand their permitting and watershed planning programs to fill gaps in the federal wetland program.

The Interagency Workgroup on Wetland Restoration, represented by the Environmental Protection Agency, National Oceanic and Atmospheric Administration, Army Corps of Engineers, Fish and Wildlife Service, and Natural Resources Conservation Service, has prepared a draft document entitled "An Introduction to Wetland Restoration, Creation, and Enhancement." This document, intended for the general public, contains a background discussion on wetlands and restoration, information on project planning and implementation, and monitoring, and will list resources, contacts, and funding sources. Relevant to this review, the document discusses the use of "reference" sites, monitoring (needs and procedures), and provides technical appendices that discuss societal goals and related ecological functions and wetland parameters and monitoring needs. For example, if the societal goal is to maintain water quality, ecological functions include retention or removal of dissolved materials, accumulation of peat (organic matter), and the accumulation of inorganic sediments. Ecological effects of these functions include reduced nutrient transport, retention of pollutants such as nutrients and metals, and sediment retention. Physical indicators include decreased nutrient concentrations at the outflow, increased depth of peat, presence of contaminants in the peat, and increased sediment depth.

**SUMMARY AND CONCLUSIONS:** A review of Corps practices indicates that most Districts have developed a procedure for compensatory wetland mitigation that is acceptable to other regulators in their area of responsibility (e.g., St. Paul District). While there are limited specific guidelines for determining loss of water quality functions, these procedures often account for locally desired functions and values at impacted sites. The amount of detail used in these procedures varies from individual, site-specific approaches to well-documented SOPs. Assessment techniques also vary, typically based on the project size and availability of site-specific data, or resources and time to collect site-specific data. Accordingly, assessment techniques vary from standard approaches such as functional assessments using the HGM approach to site-specific assessments with collected data and/or best professional judgment. There are general similarities in approaches based on

geographical settings or regional philosophies, e.g., Charleston and Savannah District SOPs and the New England (descriptive approach) and Buffalo (individual assessment approach) Districts. This segregation seems logical, since the wetland types are often similar in various regions that include multiple Districts, e.g., coastal marshes in Charleston and Savannah.

There is also a separation in assessment techniques based on size and/or data availability (e.g., the HGM approach used for large projects with existing data (Los Angeles District) and less quantitative approaches used for smaller projects (all Districts in general)). These techniques typically assess overall functional losses, not loss of individual functions, and are used to establish mitigation ratios accordingly.

While these procedures and assessment techniques utilize concepts of functions and values, there is concern that implementation is not meeting overall objectives of no-net-loss policies and mitigation banking practices and in-lieu-fee arrangements need to be modified (Scodari and Shabman 2001). Concepts of loss and substitution (mostly applied to out-of-kind replacement, banking, in-lieu-fee, and areal accounting measures (number of acres)), success and lag time (function of design), verification via monitoring and compliance enforcement, and regional/landscape approaches are not inconsistent with current Corps practices.

The recently issued Guidance Letter (RGL-01-1) promotes regional considerations, a watershed/ecosystem approach for developing compensatory mitigation, lists minimum components to be included in a mitigation plan, and provides guidance for the management of compensatory mitigation project sites. This guidance addresses several of the concerns expressed in the draft publication prepared by the NRC's Committee on Mitigating Wetland Losses.

There are certainly areas of mitigation for the loss of water quality functions that need further evaluation. Additional evaluation of water quality functions, assessment techniques, and additional development of water quality indicators that would require less intensive monitoring efforts should be conducted to increase applicability of functional assessment approaches. The use of an aggregate approach that "weights" or prioritizes individual functions for ratio determination should be evaluated. Methods that include landscape evaluations and assessment of cumulative impacts should be expanded and improved using GIS, modeling, and watershed planning approaches.

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